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Brand Rivalry, Market Segmentation, and the Pricing of Optional Engine Power on Automobiles

by

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Abstract

This paper analyzes how the pricing strategies for base automobile models may differ from those for premium models, sold with extra engine power. The popular monopoly model of market segmentation according to willingness to pay for quality is compared with two models of brand rivalry. In a first scenario, consumer are fully informed of all prices; in a second scenario, consumers are initially only informed about the prices of base models, due to selective price advertising strategies. Implications for the differences in markups between base models and premium models are drawn. These are tested with data on the European automobile market, using hedonic regression techniques. The evidence is consistent with the brand rivalry model under limited information, and inconsistent with the other two models.

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1. Introduction

Pricing practices in the automobile market have become increasingly understood in recent years. Detailed econometric work on pricing in the U.S. and European automobile markets is now available, closely following theoretical developments on the pricing of differentiated products.[1] Most of the available evidence relates to the pricing practices for the base models, the cheapest available version of a marketed model. Almost all models, however, are nowadays offered with a wide variety of options, such as extra engine power, doors, air conditioning, air bag, etc...[2] Yet, there has been virtually no systematic research to understand pricing practices for these premium models. The present paper attempts to fill this gap and provides a more systematic analysis of the differences in pricing practices between base models and premium models, sold with extra engine power.

Some casual industry wisdom indicates that premium models, with extra engine power, are sold at much higher prices than the base models they are derived from. Scherer (1980), for example, quotes an internal Ford memorandum on the Galaxie four-door sedan. The memo reveals that the wholesale price of the base model exceeded accounting costs by 17 percent, in contrast with the much higher markups charged for more powerful engines, e.g. a 293 percent markup for a V-8 engine. In a review of pricing practices in the car industry, Phlips (1983, p. 204) notes that "one has the impression that extra options are overpriced, to extract the highest possible price from those who want fancy tires or extra horsepower".

The casual empirical evidence on the pricing of optional engine power is used in several textbooks as an illustration of how firms effectively succeed in segmenting the market according to differences in the consumers' willingness to pay for quality.[3] A reference model in both economics and marketing is Mussa and Rosen's (1978) model of market segmentation. They show how a monopolist can extract higher price-cost margins from consumers with higher willingness to pay for quality. This

[1] For recent econometric contributions on the pricing of automobiles, see Horsky and Nelson (1992), Berry, Levinsohn and Pakes (1995), Goldberg (1995), Feenstra and Levinsohn (1995), and Verboven (1996). All these contibutions explicitly model automobiles as differentiated products.

[2] This used to be different long time ago. The Ford T is a famous example of a very popular model that came in just one variant.

[3] See Phlips (1984) for a theoretical analysis following the evidence on car pricing, and Tirole (1989).

can be done by offering an appropriate *menu* of price-quality combinations, inducing a self-selection of the different types of consumers.

The monopoly market segmentation model has its limitations, however. Although it predicts that *absolute* price cost margins rise with quality, *percentage* price-cost margins typically decrease, for most reasonable distribution functions of consumers' willingness to pay for quality.[4] Furthermore, a market segmentation strategy may be constrained by the presence of competition from other brands. In this case, the self-selection constraints required to segment consumers may be dominated by competitive constraints, so that even absolute margins may not be increasing. Given that both absolute and percentage margins are possibly much higher for premium models than for base models, as suggested by the above industry wisdom, a more flexible theoretical framework is desirable.

A business practice usually ignored in theoretical modelling is that of selective price advertising. Advertisements typically offer detailed information on a specific car model, with a description of all available options, including the various engine variants. Information about the price, however, is usually limited to the base model, even though it would be costless to provide information on the prices of all other variants as well. This practice may be interpreted as a means to lure customers to visit a nearby dealer, comparable to the phenomenon of loss leader pricing in grocery stores or supermarkets. If succesful, the practice of selective price advertising may be responsible for significant price and markup differences between base models and premium models.

The outline of the paper is as follows. The next section provides some relevant background literature. In section 3 a simple theoretical framework is developed that is flexible enough to understand the pricing practices of both base and premium models. Quality is modelled as in Mussa and Rosen's monopoly model, generalized to allow for competition across different brands. The model is solved under two different scenarios: a first scenario in which consumers are fully informed about all prices before they decide which model to purchase; a second scenario in which consumers are only informed about the prices of the base models, and need to visit the firm before they learn the prices of the premium models. Testable implications about the differences in markups on the base models and premium models under

[4]See Maskin and Riley (1984) and Tirole (1989).

the two different scenarios are provided, and compared with the standard monopoly model. In section 4 these testable implications are confronted with data on several European countries (Belgium, France, Germany, Italy, the United Kingdom) in 1990 and 1995. The prices for base models are compared with the prices for models with extra engine power, after adjusting for differences in cost and quality. The empirical results are consistent with the brand rivalry model with limited information (second scenario), and inconsistent with the full information brand rivalry model and the monopoly model. Section 5 concludes.

2. Background literature

Several models of competition between brands have emerged during the past two decades, both in economics and in marketing. These developments have coincided with progress in the theory of product differentiation (see Anderson, de Palma and Thisse (1991) for an overview). Two main types of product differentiation can be distinguished: horizontal and vertical. Under horizontal product differentiation, consumers are heterogeneous in that they have different "ideal" products and disagree on how to rank the actual available products. In contrast, under vertical (quality) differentiation, all consumers rank the products in the same order, according to "quality", but differ in their willingness to pay for qualities.

Brand-specific differentiation is usually viewed as horizontal product differentiation. A particularly useful model of horizontal differentiation is the logit model.[5] This model, with roots in the general area of discrete choice, has the virtue of being tractable in both theoretical and in empirical work on brand differentiation. The model has the property that consumers are heterogeneous in their willingness to pay for unobservable, brand-specific attributes. Guadagni and Little (1983) and Anderson and de Palma (1992), among others, provide theoretical analyses of the logit model as a model of brand differentiation. The number of empirical applications is increasing. Applications to the automobile industry are given by Horsky and Nelson (1992), Goldberg (1995) and Verboven (1996). The latter two applications use the more general *nested* logit model, which allows for different degrees of brand differ-

[5]The main other models of horizontal product differentiation are Hotelling's (1929) location model, and Dixit and Stiglitz (1977) representative consumer model, and the subsequent generalizations.

entiation across classes of automobiles. An empirical regularity that has arised is the higher intensity of brand rivalry in the low class and foreign segments than in the high class and domestic segments. This fact will be important in the empirical analysis below.

Some recent papers have extended the logit model of horizontal brand differentiation to vertical (quality) differentiation to consider the possibility of market segmentation. These papers are based on the monopoly model by Mussa and Rosen (1978). Moorthy (1988) extends this model to study duopoly, without allowing for brand differentiation. Rhee (1996) reconsiders Moorthy's model to allow for brand differentiation in a logit framework. He focuses on strategic quality choices and shows, consistent with empirical evidence, that firms may choose identical qualities if brands are sufficiently differentiated. Most closely related to the present paper, Katz (1984) and Gilbert and Matutes (1993) consider brand-differentiated firms selling *multiple* products of different quality.[6] Katz focuses on quality choice, assuming that consumer brand sensitivity and quality sensitivity are correlated. Gilbert and Matutes focus on entry deterrence strategies through product proliferation.

The focus in the present paper is on understanding the pattern of price-cost margins for the quality variants offered by a particular firm (brand). A simple version of Mussa and Rosen's (1978) monopoly model illustrates the problem and introduces the model proposed in the next section. Consider one firm selling one product with low quality v_L,and one with high quality v_H, at marginal cost of c_L and c_H. There are N consumers, each of whom obtains an indirect utility of $\theta v_j - p_j$ from buying $j = L, H$. The parameter θ is a consumer-specific taste parameter, measuring the marginal willingness to pay for quality. It is distributed uniformly on $[\underline{\theta}, \overline{\theta}]$. Normalize such that $\overline{\theta} - \underline{\theta} = N$. Consumers for whom $\theta < \theta^*$ prefer the low quality; consumers for whom $\theta > \theta^*$ prefer the high quality, where $\theta^* \equiv (p_H - p_L)/(v_H - v_L)$ defines the indifferent consumer's taste parameter. Assuming all consumers buy one of the two quality variants in equilibrium, market demand is given by $q_L = (\theta^* - \underline{\theta})$ and $q_H = (\overline{\theta} - \theta^*)$. Profits are $(p_L - c_L)q_L + (p_H - c_H)q_H$. The optimal high quality price p_H can be found from the first-order condition with respect to p_H:

$$p_H = p_L + \frac{c_H - c_L}{2} + \overline{\theta}\frac{v_H - v_L}{2} \tag{2.1}$$

[6] They capture brand-differentiation in a location framework, rather than in a logit discrete-choice framework.

The optimal quality price p_L is the highest price, such that the consumer with the lowest marginal willingness to pay for quality is still willing to buy, i.e. $p_L = \underline{\theta} v_L$. It is straightforward to verify that the absolute price-cost margin of the high quality product, $p_H - c_H$, is greater than the price-cost margin of the low quality product, $p_L - c_L$. However, the percentage price-cost margin of the high quality product $(p_H - c_H)/p_H$ is *less* than the percentage price-cost margin of the low quality product $(p_L - c_L)/p_L$. This can be verified from appropriate substitutions, using the constraints that market demand of the low quality product cannot be negative, and the equilibrium assumption that all consumers buy one of the two variants. These findings easily generalize to the case in which not all consumers would buy a product in equilibrium, and to a whole set of reasonable distribution functions (Tirole, 1988). In sum, the monopoly model is flexible enough to explain increasing absolute markups, but it does not explain the possibility of increasing percentage markups (unless strong distributional assumptions are made). Problems become even more severe once competition between brands is introduced. Competition further constrains the firms' capability to charge increasing price-cost margins.

To explain the possibility of increasing percentage markups, the nature of brand competition is reconsidered and made more realistic. We take the view that, in the automobile market, brand competition is not only affected by consumer heterogeneity in the valuation of unobservable brand-specific attributes; imperfect information about prices also plays a crucial role. Generally speaking, consumers are better informed about the prices of the base models than about the prices of premium models. This imperfect information is in fact encouraged by the automobile manufacturers. They heavily advertize the characteristics of their brands, describe in detail the variety of options offered, but provide information about the price of the base model only. As a result, when comparing different brands, consumers usually have a good idea about the base model prices; they need to incur extra search costs to learn about the prices of premium models. The idea of consumer search costs, reflecting imperfect information about prices, is not new. Diamond (1971) showed that the equilibrium prices of otherwise homogeneous goods are the monopoly prices, if consumers need to incur an arbitrarily small search cost to learn each price. The intuition for this result is based on the consumers' rational expectations about the equilibrium. When they visit a firm and observe a monopoly price, they are not willing to pay an additional

search cost since they expect other firms to charge the same prices in equilibrium. Lal and Matutes (1993) use a search cost model to explain loss-leader pricing, a common strategy in retailing, in which firms selectively advertize the price of some grocery items to lure consumers to the store and induce them to buy other items as well.[7] They assume that the demands for different grocery items are independent. In our model, the demands for base models and premium models will be interdependent: as the price for a base model decreases, consumers also expect a lower price for the premium model.[8]

The model developed and analyzed in the next section, considers two alternative scenarios, one in which consumers are fully informed about all prices, another in which they are informed only about the prices of the base models before they visit a firm. The model is admittedly simple. For example, it would have been more realistic to "nest" the two scenario's into one model by assuming a proportion λ of uninformed consumers, and a proportion $1-\lambda$ of informed consumers, who may visit several firms at no cost, as in Salop and Stiglitz (1977). The analysis also abstracts from issues such as the choices which qualities to offer and which qualities to advertize. Instead, it focuses on explaining the pattern of markups across different variants of the same brand, given a realistic description of observed quality and advertizing choices in the automobile industry.

3. The model

Consider the following stylized model of competition in the automobile industry. There are two firms, 1 and 2, each selling one specific brand. Each firm i offers its brand in two different variants, a base model with a low quality v_L and a premium model with a high quality v_H. Firm i sells its base model at a price p_{iL}, its premium model at a price p_{iH}. Marginal costs are c_L and c_H, respectively. There are N consumers, all endowed with income I, purchasing one of the goods. A consumer obtains the following indirect utility from variants L and H of the brand sold by firm $i = 1, 2$.

$$u_{iL}(\theta) = I + v_L\theta - p_{iL} + \varepsilon_i \tag{3.1}$$

[7] See Hess and Gerstner (1987) for an early analysis of loss leader pricing.

[8] See Semester (1995) for a different mechanism in which firms can signal a price image through advertising.

$$u_{iH}(\theta) = I + v_H\theta - p_{iH} + \varepsilon_i, \tag{3.2}$$

where θ and ε_i are random variables, capturing consumer heterogeneity in the willingness to pay for quality and in brand preference. First, consumers may differ in their marginal willingness to pay for quality, θ. Assume θ is uniformely distributed across consumers on the interval $[\underline{\theta}, \overline{\theta}]$. Intuitively, if the difference between $\overline{\theta}$ and $\underline{\theta}$ is large, then consumers differ much in their willingness to pay for quality; if $\overline{\theta} = \underline{\theta}$, then all consumers have the same willingness to pay for quality. Without loss of generality, let $\overline{\theta} - \underline{\theta} = N$. With this normalization, demands and market shares will coincide. Second, consumers may differ in their brand preference. Each brand contains numerous attributes, such as style, image or comfort, which consumers may evaluate differently. The random variable ε_i denotes a consumer's willingness to pay for a specific brand i: it enters the indirect utility of both the base model and the premium model of brand i. Assume, as in the popular logit model, that ε_1 and ε_2 are distributed identically and indepentently according to the type I extreme value distribution, with a mean zero and standard deviation $\pi\sigma/\sqrt{3}$.[9] If $\sigma = 0$, then there is no heterogeneity in brand-specific preferences; brand 1 and 2 are essentially homogeneous goods. As σ increases, consumers become heterogeneous in that they are more likely to value the two brands differently. The parameter σ will be important in what follows. It allows to capture the degree of competition stemming from heterogeneity in brand preference.

Two alternative scenarios are considered. In the first scenario, consumers are fully informed about all prices before they visit a firm and choose a variant. This scenario is likely to be applicable if firms heavily advertise the prices of all variants they sell, and if, in addition, consumers have good computational skills in that they face no problems in comparing the prices of all brands and variants. In the second scenario, consumers are only informed about the prices of the base models. To learn the prices of the premium models they need to engage in costly "search". One interpretation of this costly search is that firms only advertize the prices of the base models; consumers need to visit the firm, at a cost, to learn the prices of the premium models. Another, complementary interpretation is that consumers have limited computational skills. They use the base model prices as reference prices to

[9] See e.g. Anderson, de Palma and Thisse (1992) for details on the logit model.

choose among different brands, and only form vague expectations on the prices for the premium models. Both interpretations yield a positive consumer search cost $s > 0$. The consideration of two alternative scenarios is for expositional convenience. It would be more realistic to the integrate the two scenario's into one model, for example by assuming that a proportion λ of consumers is perfectly informed, and a proportion $1 - \lambda$ is only partially informed. This, however, would considerably complicate the analysis without generating new insights. The alternative scenario's are now described in more detail.

Scenario 1. Full information about prices

In stage 1, firms simultaneously announce to consumers which price they charge for the both base model and the premium model. In stage 2, consumers choose which firm to visit and which variant to buy at that firm, based on the prices announced in stage 1.

Scenario 2. Limited information about prices

In stage 1A, both firms simultaneously announce to consumers which price they charge for the base model. In stage 1B, consumers form expectations of the prices charged for the premium models and firms set the actual prices of the premium models. In stage 2, consumers choose which firm to visit, based on the announced base model prices and the expected premium model prices. They learn the actual price of the premium model at the firm they visit, and decide whether to buy one of the two variants and, if so, which one. If they choose not to buy either of the variants, they can visit the rival firm in stage 3 at a search cost $s > 0$. Upon visting the rival firm in stage 3, the consumer learns all prices, and is free to choose which variant to buy from which firm.

In both scenarios, each firm chooses prices to maximize profits, given the prices set simultaneously by the rival firm, and in anticipation of the equilibrium decisions taken by firms and consumers in the following stages of the game. Similarly, in both scenarios consumers choose which firm to visit and which variant to buy to maximize (expected) indirect utility, as given by 3.1 and 3.2. In scenario 2, consumers need to form expectations about the prices of the unannounced premium models. I will require these expectations to be rational, i.e. consistent with the assumptions of the model. Consumers use their knowledge of the game, including the fact that

firms choose prices to maximize profits, to forecast how the unannounced premium model prices depend on the announced base model prices. Of course, in equilibrium these forecasts are correct, and firms do not "surprise" consumers. Consequently, in scenario 2, consumers always buy one of the variants from the store they visited in stage 2; no consumer is surprised and finds it necessary to incur the positive search cost s to visit the other firm in stage 3.

4. Analysis

4.1. Aggregate demands

First consider, for both scenario's, the consumers' decision in stage 2: which firm to visit and which variant to buy, given the observed and expected prices. This amounts to deriving the aggregate demand function for each of the four brand/variants. Let p^e_{iL} and p^e_{iH} be the expected price of the base model and premium model sold by firm i. Obviously, for an announced price (i.e. all prices under scenario 1, and the base model prices under scenario 2), we have $p^e_{iL} = p_{iL}$ and $p^e_{iH} = p_{iH}$. For an unannounced price of the premium model, we have $p^e_{iH} = p^e_{iH}(p_{iL})$, where $p^e_{iH}(.)$ is a function to be derived later, reflecting the dependence of expected premium model prices on the observed base model prices.

The consumer's decision can be broken down in two parts. First, for each brand, the consumer decides which variant of that brand is preferred. This decision crucially depends on the marginal willingness to pay for quality θ. From comparing 3.1 and 3.2 it is obvious that consumers with a relatively low marginal willingness to pay for quality, $\theta < \theta^*_i$, prefer the base model variant of brand i; consumers with $\theta > \theta^*_i$ prefer the premium model, where θ^*_i is the indifferent consumer's marginal willingness to pay for quality, i.e.

$$\theta^*_i \equiv \frac{p^e_{iH} - p^e_{iL}}{v_H - v_L}.$$

Second, the consumer compares the preferred variants of the two different brands. Table 1 summarizes which comparisons the consumers make.

For example, if $\theta^*_1 < \theta^*_2$, then a consumer with $\theta \in [\theta^*_1, \theta^*_2]$ prefers the premium model of brand 1 to the base model, and prefers the base model of brand 2 to the premium model, so that he compares brand 1's premium model with brand 2's base

model. The outcomes of the cross-brand comparisons are probabilistic and depend on the extreme value distributed random variables ε_1 and ε_2, measuring heterogeneity in brand preference. The probability that a consumer, with quality taste parameter θ, prefers brand 1 with variant j, $j = L, H$, over brand 2 with variant k, $k = L, H$, is given by the standard logit formula:

$$\Pr(u_{1j}(\theta) \geqslant u_{2k}(\theta)) = \frac{\exp((v_j\theta - p^e_{1j})/\sigma)}{\exp((v_j\theta - p^e_{1j})/\sigma) + ((v_k\theta - p^e_{2k})/\sigma)}.$$

Note that $\Pr(u_{2k}(\theta) \geqslant u_{1j}(\theta)) = 1 - \Pr(u_{1j}(\theta) \geqslant u_{2k}(\theta))$. Given that the quality taste parameter θ is uniformly distibuted on $[\underline{\theta}, \bar{\theta}]$, the aggregate demand for the base model of brand 1 is given by:

$$q_{1L} = \begin{cases} 0 & \text{for} \quad \theta_1^* < \underline{\theta} \\ \int_{\underline{\theta}}^{\theta_1^*} \frac{\exp(-p^e_{1L}/\sigma)}{\exp(-p^e_{1L}/\sigma)+\exp(-p^e_{2L}/\sigma)} d\theta & \text{for} \quad \underline{\theta} \leqslant \theta_1^* < \theta_2^* \\ \int_{\underline{\theta}}^{\theta_2^*} \frac{\exp(-p^e_{1L}/\sigma)}{\exp(-p^e_{1L}/\sigma)+\exp(-p^e_{2L}/\sigma)} d\theta + & \\ \int_{\theta_2^*}^{\theta_1^*} \frac{\exp(-p^e_{1L}/\sigma)}{\exp(-p^e_{1L}/\sigma)+\exp(\theta(v_H - v_L)-p^e_{2H}/\sigma)} d\theta & \text{for} \quad \theta_2^* \leqslant \theta_1^* < \bar{\theta}. \end{cases} \tag{4.1}$$

Intuitively, there are three cases to consider, depending on the value of θ_1^*. If p^e_{1L} is very high so that $\theta_1^* < \underline{\theta}$, then any consumer prefers the premium model to the base model of brand 1, and demand q_{1L} is zero. If p^e_{1L} is moderately high so that $\underline{\theta} \leqslant \theta_1^* < \theta_2^*$, then all consumers for which $\theta \in [\underline{\theta}, \theta_1^*]$, compare the base model of brand 1 with the base model of brand 2. Integrating the relevant choice probabilities over the range $[\underline{\theta}, \theta_1^*]$, then yields the aggregate demand formula for case 2. (Note that the terms θv_L cancel in the formula for case 2.) If p^e_{1L} is low so that $\theta_2^* \leqslant \theta_1^* < \bar{\theta}$, then all consumers for whom $\theta \in [\underline{\theta}, \theta_2^*]$, compare the base model of brand 1 with the base model of brand 2, and all consumers for whom $\theta \in [\theta_2^*, \theta_1^*]$, compare the base model of brand 1 with the premium model of brand 2. Integrating the relevant choice probabilities over the two ranges $[\underline{\theta}, \theta_2^*]$ and $[\theta_2^*, \theta_1^*]$ then yields the aggregate demand formula for case 3. A similar reasoning yields aggregate demand for the premium model of brand 1, depending on the level of θ_1^*:

$$q_{1H} = \begin{cases} 0 & \text{for } \overline{\theta} < \theta_1^* \\ \int_{\theta_1^*}^{\overline{\theta}} \frac{\exp(-p_{1H}^e/\sigma)}{\exp(-p_{1H}^e/\sigma)+\exp(-p_{2H}^e/\sigma)} d\theta & \text{for } \theta_2^* \leqslant \theta_1^* < \overline{\theta} \\ \int_{\theta_1^*}^{\theta_2^*} \frac{\exp(-p_{1H}^e/\sigma)}{\exp(-p_{1H}^e/\sigma)+\exp(-\theta(v_H-v_L)-p_{2L}^e/\sigma)} d\theta + & \\ \int_{\theta_2^*}^{\overline{\theta}} \frac{\exp(-p_{1H}^e/\sigma)}{\exp(-p_{1H}^e/\sigma)+\exp(-p_{2H}^e/\sigma)} d\theta & \text{for } \underline{\theta} \leqslant \theta_1^* \leqslant \theta_2^*. \end{cases} \tag{4.2}$$

The demand function for the base and premium models of brand 2, q_{2L} and q_{2H}, can be analogously derived. In the Appendix, it is explained how to obtain a closed-form solution for the demand functions.

4.2. Pricing decisions

Firms set prices to maximize profits, as given by

$$\pi_i = (p_{iL} - c_L)q_{iL} + (p_{iH} - c_H)q_{iH}$$

for each firm i. Consider first the pricing decisions in scenario 1. As explained above, all price decisions are taken in stage 1, simultaneously by both firms, in anticipation of consumer choices in stage 2. Consumer choices have been derived in the previous subsection, and are summarized by the demand functions 4.1 and 4.2. Because all prices are announced in scenario 1, one can replace the expected prices p_{iL}^e and p_{iH}^e in the demand functions by the actual prices p_{iL} and p_{iH}. Firm 1's first-order condition for profit maximization, with respect to p_{1L} and p_{2H}, are given by:

$$\begin{aligned} (p_{iL} - c_L)\frac{\partial q_{1L}}{\partial p_{1L}} + q_{1L} + (p_{iH} - c_H)\frac{\partial q_{1H}}{\partial p_{1L}} &= 0 \\ (p_{iL} - c_L)\frac{\partial q_{1L}}{\partial p_{1H}} + (p_{iH} - c_H)\frac{\partial q_{1H}}{\partial p_{1H}} + q_{1H} &= 0 \end{aligned}$$

and similarly for firm 2. Given the symmetry in the model, focus on finding a symmetric equilibrium, $p_{1L} = p_{2L} = p_L$ and $p_{1H} = p_{2H} = p_H$. Proving the existence of an equilibrium is beyond the scope of the present paper. Although there are good reasons to expect that an equilibrium does indeed exist[10], simply assume here that this is the case. The demand derivatives, after imposing symmetry, are easily

[10]The assumption of Caplin and Nalebuff's (1991) model are satisfied, so an equilibrium would exist if there would be four single-product firms, each selling one of the brand/variants. Proving existence with multiproduct firms is more difficult, though it has been shown in a variety of models that have some of the features of the present model, see e.g. Anderson, de Palma and Thisse (1991). A direct proof consists of showing that the profit functions are quasi-concave in the present model.

computed; they are presented in the Appendix. They allow to write the first-order conditions as:

$$\begin{aligned}(p_L - c_L)(\theta^* - \underline{\theta}) = 2\sigma(2\theta^* - \underline{\theta} - \tfrac{c_H - c_L}{v_H - v_L}) &= 0 \\ (p_H - c_H)(\overline{\theta} - \theta^*) = 2\sigma(\overline{\theta} - 2\theta^* + \tfrac{c_H - c_L}{v_H - v_L}) &= 0,\end{aligned} \tag{4.3}$$

where $\theta^* \equiv (p_H - p_L)/(v_H - v_L)$. We have:

Proposition 1. *When there is full information about prices (scenario 1), a unique symmetric equilibrium is given by*

$$\begin{aligned}p_L &= c_L + 2\sigma \\ p_H &= c_H + 2\sigma.\end{aligned} \tag{4.4}$$

Proof: It is straightforward to verify that 4.4 satisfies the first-order conditions. Since 4.3 can be reduced to one cubic in p_L and another in p_H, there remain two other solutions to consider. Factoring out the solution 4.4, leaves a quadratic, from which the remaining solutions can be computed. It can be verified that there are two real solutions for the prices. However, they are inconsistent with the model since they either yield negative demand for the base models, or negative demands for the premium models.

Proposition 1 implies that firms charge the same absolute markup for the base model as for the premium model, i.e. 2σ. This is in stark contrast with the monopoly model, which predicts that markups that are increasing in quality. Somewhat surpisingly, with brand rivalry firms are not able to segment consumers according to their willingness to pay for quality θ *for any level of competition*, i.e. for any degree of heterogeneity in brand preference.

Consider next the pricing decisions in scenario 2. As explained above, pricing decisions are taken and announced to consumers in stage 1A about the base models only, so that one can set $p^e_{iL} = p_{iL}$ in the demand functions. The pricing decisions for the premium models are taken in stage 1B, simultaneous with the formation of consumer expectations about these prices. With rational expectations, consumer forecasts are correct and firms do not surprise consumers in stage 1B. I claim that the expected and the actual price of the premium model, p^e_{iH} and p_{iH}, as formed in stage 1B, equal the monopoly price, i.e. the price that firm i would set for the

premium model in the absence of any competition from its rival, given the price it already chose for the base model. Formally,

$$p_{iH}^e = p_{iH} = p_{iH}^m \equiv p_{iL} + \frac{c_H - c_L}{2} + \overline{\theta}\frac{v_H - v_L}{2}, \tag{4.5}$$

as is obvious from the discussion of the monopoly model and 2.1 in section 2. Note that, as consumers observe a lower price for the base model p_{iL}, they expect a lower price for the premium model as well. In this sense, base model prices signal expected premium model prices.[11] The proof of why firms (are expected to) charge the monopoly price follows a similar reasoning as in Diamond (1971) or Lal and Matutes (1994). For a candidate equilibrium price below this monopoly price, say p'_{iH} each firm has an incentive to deviate and surprise the consumers that visited the firm, by setting a slightly higher price, i.e. $p'_{iH} + \epsilon$, with ϵ sufficiently small so that $\epsilon < s$. Under this surprise price, no consumer finds it worthwhile to visit the rival firm where they expect to pay the candidate equilibrium price p'_{jH}. Hence, from slightly increasing the price of its premium model, the firm would loose no market share to its rival and would come closer to its preferred monopoly. Only at the first-best monopoly price, given the price of the base model, set in stage 1A, do firms have no incentive to raise their price. Similarly, and obviously, firms do not have an incentive to lower their price of the premium level below the monopoly price: this is a happy surprise to consumers who visited the firm, but it fails to attract the ignorant consumers who visited the rival.

From 4.5, it immediately follows that firms segment consumers according to willingness to pay for quality. Higher absolute markups are charged to consumers with a high willingness to pay for quality, exactly as in the monopoly model, see Table 2. To investigate whether firms also have incentives to charge higher percentage markups to quality sensitive consumers, it is necessary to derive the actual equilibrium prices for the base models, which firms set and announce simultaneously in stage 1A.

Firm 1's first-order condition for profit maximization with respect to p_{1L}, given aggregate demands after substituting the expected prices, specifically 4.5, is:

$$(p_{1L} - c_L)\frac{\partial q_{1L}}{\partial p_{1L}} + q_{1L} + (p_{1H} - c_H)\frac{\partial q_{1H}}{\partial p_{1L}} + \frac{\mathrm{d}p_{1H}}{\mathrm{d}p_{1L}}q_{1H}. \tag{4.6}$$

[11] This contrast with Lal and Matutes (1994). See Simester (1995) for an interesting different signalling mechanism with advertized prices.

Note that this first-order condition is distinct from firm 1's first-order condition with respect to p_{1L} in two respects. First, the partial demand derivatives $\partial q_{1L}/\partial p_{1L}$ and $\partial q_{1H}/\partial p_{1L}$ differ, because a unit reduction in p_{1L} in stage 1A will yield the same unit reduction in p_{1H} in stage 1B, as can be seen from 4.5. The exact demand derivatives are computed in the Appendix. Second, the last term is new; its interpretation is analogous to the interpretation of the second term. A small reduction in the price p_{1L} implies a "traditional" loss on the sales of the base model, a loss of $-q_{1L}$; in addition, however, it implies that firm 1 will lower the price of the premium model in stage 1B, by $\mathrm{d}p_{1H}/\mathrm{d}p_{1L}$ which equals 1, see 4.5, implying an additional loss on the sales of the premium model of $-q_{1H}$. A similar first-order condition holds for firm 2. Again focus on finding a symmetric equilibrium. A unique symmetric equilibrium is found from solving and simplifying the linear system 4.5 and 4.6. This immediately yields:

Proposition 2. *When information about prices is limited to the base model prices (scenario 2), the unique equilibrium is given by*

$$\begin{aligned} p_L &= c_L + 2\sigma - \tfrac{v_H - v_L}{\overline{\theta} - \underline{\theta}} \left(\tfrac{\overline{\theta}}{2} - \tfrac{c_H - c_L}{2(v_H - v_L)} \right)^2 \\ p_H &= c_H + 2\sigma + \tfrac{v_H - v_L}{\overline{\theta} - \underline{\theta}} \left(\tfrac{\overline{\theta}}{2} - \tfrac{c_H - c_L}{2(v_H - v_L)} \right) \left(\tfrac{\overline{\theta}}{2} + \tfrac{c_H - c_L}{2(v_H - v_L)} - \underline{\theta} \right). \end{aligned}$$

This may be compared to the equilibrum with full information about prices. The absolute markup on the base model is *lower* when there is limited information than when there is full information; the absolute markup on the premium model is *higher* when there is limited information than when there is full information. Intuitively, firms compete vigourosly for consumers through the prices of the base models, in anticipation of the large monopoly profits to be earned from the premium models. Overall profits, however, are the same, equalling $\sigma(\overline{\theta} - \underline{\theta})$ in both scenarios. In the extreme case in which there is no heterogeneity in brand preferences, profits are zero, with negative base model profits exactly compensating positive premium model profits.

Table 2 compares the percentage markups of the base and premium models, in the monopoly case and the cases of brand rivalry with full and imperfect information about prices. In the monopoly case, percentage markups of premium models are less than percentage markups of base models. The same is true if there is brand rivalry with full price information. However, the difference in percentage markups becomes

very small as σ approaches infinity. In the case of brand rivalry with limited price information, the pattern of percentage markups is fundamentally different. For small degrees of brand heterogeneity, and correspondingly vigourous competition ($\sigma < \sigma^*$), the percentage markup may be significantly smaller for the base model than for the premium model. This is obvious for the extreme case in which $\sigma = 0$, so that markups are negative for the base model and positive for the premium model. Only for significant brand heterogeneity, and correspondingly soft competition ($\sigma > \sigma^*$), is the percentage markup for the base model larger than for the premium model, although this difference becomes very small as σ approaches infinity.

5. Empirical Results

The theoretical framework developed in the previous sections is now applied to the pricing of optional engine power on automobiles. Hedonic regressions are estimated to investigate systematic differences in pricing behavior on base models and premium models.

The automobile industry is well-suited for our purposes. There is detailed empirical evidence on the intensity of brand rivalry in the automobile market, and on differences in this intensity across different market segments. This is important, since the intensity of brand rivalry, as captured by the heterogeneity parameter σ, is crucial in distinguishing between alternative theories of pricing (recall Table 2). Several industry and marketing studies classify the automobile industry in various segments, according to two criteria: class and country of origin. The classes are defined according to common characteristics of the cars, such as size and performance. Commonly used class labels are: subcompact, compact, intermediate, standard, luxury, sports and utility. Country of origin is believed to be important, since cars from the same country of origin are perceived as similar by consumers and are normally subject to the same type of trade restrictions.

Consistent with industry wisdom, econometric studies suggest the following about the intensity of brand rivalry in different segments. First, brand rivalry is very intense in the low class segments of the market, such as the subcompacts and the compacts. In the higher class segments, brand rivalry tends to be softer, especially in the standard, luxury and sports segments. One explanation comes directly from the theoretical model developed above: consumers are relatively homogeneous in

their preferences for low class models (low σ). For high class models they tend to disagree more about which brand, e.g. BMW or Mercedes, they prefer (high σ). An alternative explanation for the differences in brand rivalry is not explicitly captured in the simple theoretical framework, but would yield similar conclusions: the number of competing brands tends to be higher in the low class segments than in the high class segments. Second, brand rivalry is more intense in the foreign segments than in the domestic segments. This can again be explained by two factors: foreign brands are perceived as more similar and there are many more competing foreign brands than domestic brands. Econometric evidence on these findings is provided, among others, by Bresnahan (1981), Mertens and Ginsburgh (1985) and Berry, Levinsohn and Pakes (1995). Most closely related to the theoretical framework of this paper, are the studies by Horsky and Nelson (1992), Goldberg (1995) and Verboven (1996). Goldberg and Verboven use a nested logit model of brand rivalry, allowing for different intensities of brand rivalry in different segments, and obtain similar findings on the intensity of rivalry in different segments.

A base model is defined as the cheapest available variant of a model. As premium models I consider models that come with extra engine power. I do not consider pricing of other options, such as extra number of doors or air bag, for several reasons. First, a comparison between the base model prices and the prices of other premium models, such as extra number of doors, does not easily allow to control directly for differences in quality, since the number of doors in the base models are usually the same (or does not vary by much). In contrast, horsepower and displacement, which determine engine power, vary a lot across different base models, so that it is possible to obtain an estimate of the effect of engine power on price, and control for this when examining the prices of premium models with extra engine power. Second, options other than extra engine power, are often offered for free in special sales promotions. Such practices require further theoretical work, related to the literature on price promotions, and more detailed data.

Consider a general reduced form expression for the price of a brand/variant i:

$$p_i = c_i(v_i) + m_i(\mathbf{v})p_i.$$

where $c_i(v_i)$ is the marginal cost of i as a function of quality v_i, and $m_i(\mathbf{v})$ is the reduced form solution for the percentage markup as a function of the vector of $\mathbf{v}$,

containing all competing brand/variants' qualities. Note that quality v_i enters both marginal cost and markup in (14), so that special care must be taken to distinguish high prices due to high marginal costs from high prices due to high markups. In particular, it will not be possible to estimate the exact markups in the above reduced-form framework; it will, however, be possible to say something about *differences* in markups between base and premium models under reasonable identification assumptions. Expression (14) can be approximated by $\ln(p_i) \simeq \ln c(v_i) + m_i(\mathbf{v})$. Estimate this by the following hedonic regression:

$$\begin{aligned} \ln(p_i) &= x_i\gamma + \alpha_m + \alpha_f + \alpha_g + \alpha_h \\ &+ \overline{\alpha}_g + \overline{\alpha}_h + \varepsilon_i. \end{aligned}$$

The first row contains elements interpreted to influence both marginal costs and markups. The vector x_i contains the physical characteristics of brand/variant i, such as horsepower, displacement, turbo, injection, weight and size. The fixed effects α_m and α_f are, respectively, market-specific and firm-specific effects, estimated using dummy variables. Five markets are considered: Belgium, France, Germany, Italy and the United Kingdom. Prices may be high, say in the U.K., because of high marginal costs of selling or because of high markups in that country.[12] The following firms are considered: Fiat, Ford, GM, Peugeot, Renault and Volkswagen. Once again, prices of one firm may be high because of high marginal costs or because of high markups. The class-specific effects α_g may capture unobserved characteristics influencing marginal cost, common to all firms in a class. Yet, given the detailed econometric evidence from the structural model estimates referred to above, it is reasonable to expect that they capture class-specific markups to a significant extent. Similarly, the country-of-origin-specific effects α_h (domestic versus foreign) may capture lower marginal costs to domestic firms (e.g. because of transportation costs or trade restrictions). Yet again, it is reasonable to attribute a significant part of these effects to different markups, given the structural econometric evidence on differences in market power between domestic and foreign firms.[13]

The fixed effects $\overline{\alpha}_g$ and $\overline{\alpha}_h$ are interpreted to capture the extra percentage

[12] In a structural model, Verboven (1996) distinguishes between these two possibilities.

[13] Japanese brands were excluded from the sample to avoid the problem of how to deal with the quota constraints which influence markups. This is already difficult enough in structural models, see Goldberg (1995) and Verboven (1996).

markup (possibly negative) charged on a premium model from class g and from country of origin h, respectively. Crucially, I allow the extra markup charged on the premium model to be different across classes and country of origins, in accordance with the theoretical framework which predicts different extra markups depending on the intensity of brand rivalry in a given segment (Table 2). It is reasonable to assume that $\overline{\alpha}_g$ and $\overline{\alpha}_h$ do not reflect an extra marginal cost in producing the premium model. The premium models only differ from the base models in that they contain extra engine power, and this is already carefully controlled for by the physical characteristics horsepower, displacement, turbo and injection. In this respect, it is especially important to note that I controlled for turbo and injection, which may significantly influence marginal costs of premium models. Indeed, typically, base models tend to come without turbo and injection, whereas several premium models are equipped with one or both of these features. Therefore, if turbo and injection had been excluded, the estimates of $\overline{\alpha}_g$ and $\overline{\alpha}_h$ could take over their effects on marginal cost.

The empirical results from the hedonic regression are presented in Table 3. To check for the robustness of the results the regression was applied to a set of brand variants in both 1990 and 1995, yielding a total number of brand/variant observations of 1256. Although not all parameter estimates were stable over the two periods, the parameters of main interest, measuring the extra markups on premium models, are stable. I therefore present the results for a pooled regression, allowing unrestricted estimation of the significantly unstable parameters. Most parameter estimates are intuitive. The parameter estimates of the physical characteristics have the expected sign and they are significant, except for the insignificant estimates of the weight and injection parameters. The estimates of market- and firm-specific fixed effects are consistent with other studies. They are not stable over the two periods; the main reason for this are the large fluctuations of exchange rates between 1990 and 1995.

The estimates of the class-specific effects are consistent with industry wisdom and previous econometric evidence on the car market. Relative to the subcompact class, the compact class is 15 percent more expensive, after controlling for differences in characteristics. Similarly, the intermediate, standard and luxary segments are between 23 and 36 percent more expensive. Although this may come in part from class-specific costs, it is reasonable to attribute a significant part to class-specific

markups. The domestic fixed effect is significantly positive. Domestic brand/variants are about 4 percent more expensive than foreign brands. Given that domestic firms are likely to have a marginal cost advantage over foreign firms (of up to 10 percent in Verboven's (1996) structural estimates), one may expect that actual markups on domestic models are even more than 4 percent larger.

It is now possible to turn to an interpretation of the estimates of the extra markups charged for the premium models. The estimates reveal that premium models are priced significantly higher than base models in the low, subcompact class and in the foreign segment. A premium model of a domestically produced subcompact car is 8 percent more expensive than the base model, after controlling for differences in engine power; a premium model of a foreign subcompact car is even 11 percent (8+3 percent) more expensive. In sharp contrast, premium models of the other, higher classes are sold at percentage discounts, though not significantly different from zero.

Without a theoretical framework these contrasting results can only be explained with some *ad hoc* reasoning. But using the theoretical findings from the previous sections, summarized in Table 2, these results can be interpreted as being consistent with the model of brand rivalry under imperfect information (scenario 2), and as inconsistent with both the monopoly model and the model of brand rivalry with full information (scenario 1). When consumers are not well informed about the prices of premium models, they base their brand choices initially on the prices of the base models. This gives firms an incentive to convince consumers to purchase their brand by charging low (sometimes below cost) prices for base models of their brand. Once consumers have been attracted to their particular brand, market power results and firms can charge high monopolistic prices for the premium models. This results in large percentage markup differences between base and premium models if brand rivalry is intense. In contrast, if brand rivalry is not so intense, equilibrium markups on the base models may be fairly large, so that the extra percentage markup charged for premium models can be small or negative. It is precisely in the segments in which brand rivalry is most intense (subcompact and foreign) that percentage markups for premium models are significantly higher. This evidence thus suggests that the model of brand rivalry with limited information on the prices of premium models (scenario 2) is a good description of competition in the automobile industry. The widely observed selective advertizing strategies, providing information solely on

the base model prices, possibly in combination with limited consumer computational skills, may thus be interpreted as important determinants of the pattern of markups in the automobile market.

6. Concluding remarks

This paper has compared pricing practices on base and premium models, with extra engine power, in the automobile industry. Various alternative models, with alternative predictions about the pattern of markups, have been considered: a monopoly model, a model of brand rivalry with full consumer information and a model of rivalry in which consumers are only well informed about base model prices. The empirical results, from hedonic regression estimates, provide evidence in favor of the limited information model.

This paper only begins to improve our understanding of the differential pricing practices between base model and premium models. The theoretical framework, with brand differentiation and imperfect information, captures, I believe, the essential features of the pricing behavior for automobiles. Nevertheless, it is worth making the model more realistic and estimate a structural model of pricing. For this, it is necessary to extend the model to more than two firms, with differing marginal costs and qualities, in a nested rather than simple logit framework. Scenario's 1 and 2 could be combined in one model by assuming a proportion of fully informed, and another proportion of limitedly informed consumers. Such a model could be estimated structurally, with data on sales of the various brands and variants in addition to the data used above. Needless to say, such an approach could be computationally rather intractable.

From a theoretical perspective, it would be interesting to analyze firms' decisions prior to the pricing stage in the present model. Two scenario's have been considered, one in which firms advertize all prices, another in which they advertize only base model prices. It would be interesting to investigate the equilibrium incentives for firms to advertize, under alternative intensities of brand rivalry. Applications would extend well beyond the automobile case. Similarly, it would be interesting to analyze the firms' quality choices in the developed framework.

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8. Appendix

The demand equations (4.1.) and (4.2.) can easily be solved in closed form, noting that $\int \mathrm{d}\theta = \theta$ and

$$\int \frac{a}{a+b\exp(c\theta)}\mathrm{d}\theta = \theta - \frac{1}{c}\ln(a+b\exp(c\theta)).$$

The demand derivatives in scenario 1, imposing symmetry, are can then be computed:

$$\begin{array}{lcl} \frac{\partial q_{1L}}{\partial p_{1L}} & = & -\frac{1}{4\sigma}(\theta^* - \underline{\theta}) - \frac{1}{2(v_H - v_L)} \\ \frac{\partial q_{1L}}{\partial p_{1H}} = \frac{\partial q_{1H}}{\partial p_{1L}} & = & \frac{1}{2(v_H - v_L)} \\ \frac{\partial q_{1H}}{\partial p_{1H}} & = & -\frac{1}{4\sigma}(\overline{\theta} - \theta^*) - \frac{1}{2(v_H - v_L)}. \end{array}$$

Similarly, the demand derivatives in scenario 2 are, after substituting (4.5) into (4.2):

$$\begin{array}{lcl} \frac{\partial q_{1L}}{\partial p_{1L}} & = & -\frac{1}{4\sigma}(\frac{c_H - c_L}{2(v_H - v_L)} + \frac{\overline{\theta}}{2} - \underline{\theta}) \\ \frac{\partial q_{1H}}{\partial p_{1L}} & = & -\frac{1}{4\sigma}(\frac{\overline{\theta}}{2} - \frac{c_H - c_L}{2(v_H - v_L)}). \end{array}$$

9. Tables

Table 1. Consumer comparisons of variants across brands	
$\theta_1^* < \theta_2^*$	$\theta_1^* > \theta_2^*$
if $\theta \in [\underline{\theta}, \theta_1^*]$, compare 1L with 2L	if $\theta \in [\underline{\theta}, \theta_2^*]$, compare 1L with 2L
if $\theta \in [\theta_1^*, \theta_2^*]$, compare 1H with 2L	if $\theta \in [\theta_2^*, \theta_1^*]$, compare 1L with 2H
if $\theta \in [\theta_2^*, \overline{\theta}]$, compare 1H with 2H	if $\theta \in [\theta_1^*, \overline{\theta}]$, compare 1H with 2H

Table 2. Difference in markups on premium and base model			
	monopoly	duopoly (scenario 1)	duopoly (scenario 2)
absolute markups	+	0	+
$(p_H - c_H) - (p_L - c_L)$	difference independent of σ		
percentage markups $\frac{p_H - c_H}{p_H} - \frac{p_L - c_L}{p_L}$	—	0 for $\sigma = 0$ — for $\sigma > 0$ $\to 0$ as $\sigma \to \infty$	+ for $\sigma < \sigma^*$ 0 for $\sigma = \sigma^*$ — for $\sigma > \sigma^*$ $\to 0$ as $\sigma \to \infty$
$\sigma^* = \frac{1}{\overline{\theta} - \underline{\theta}} \frac{v_H - v_L}{2(c_H - c_L)} \left(\frac{\overline{\theta}}{2} - \frac{c_H - c_L}{2(v_H - v_L)}\right) \left(c_H \left(\frac{\overline{\theta}}{2} - \frac{c_H - c_L}{2(v_H - v_L)}\right) + c_L \left(\frac{\overline{\theta}}{2} + \frac{c_H - c_L}{2(v_H - v_L)} - \underline{\theta}\right)\right)$			

Table 3. Hedonic Regression, unstable specification, 1256 observations					
		1990 estimates		significant 1995 differences	
	variable	parameter	stand. error	parameter	stand. error
	constant	7.405	.171	.218	.016
characteristics	displacement	.133	.017		
	horsepower	.552	.019		
	turbo	.051	.016		
	injection	.008	.010		
	weight	.115	.502		
	width	.119	.029		
market-specific	France	.045	.012	.008	.017
effects (α_m),	Germany	.090	.013	-.044	.018
relative to	Italy	.151	.012	-.251	.018
Belgium	U.K.	.218	.012	-.266	.018
firm-specific	Ford	.020	.012	.072	.015
effects (α_f),	GM	-.013	.013	.045	.018
relative to	Peugeot	.020	.012	.072	.015
Fiat	Renault	.015	.015	.062	.019
	Volkswagen	.075	.015	-.003	.020
class	compact	.150	.020		
effects (α_g),	intermediate	.227	.024		
relative to	standard	.306	.035		
subcompacts	luxary	.360	.040		
dom. effect (α_h)	domestic	.040	.014		
premium effects	subcompact	.084	.017		
($\overline{\alpha}_g$ and $\overline{\alpha}_h$)	compact	-.025	.017		
	intermediate	-.028	.017		
	standard	-.023	.020		
	luxary	-.019	.027		
	foreign	.032	.014		